

Final Technical Report

ONR Grant # N00014-92J-1154

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Small-scale biophysical interactions



The long-term goal of this project was to better understand and quantify the coupling between physical and biological processes on a variety of temporal and spatial scales. We were especially interested in the role of mixing as it influences the rates of biological processes.

Our specific objectives were to:

- quantify the relationship between the microscale physical structure of the water column and the microscale distribution of phytoplankton biomass;
- quantify the time scales of bio-physical correlations over the microscale, especially in relation to the time scales predicted from first principles;
- evaluate the correlation between temperature and/or density steps (gradients) and the observed small-scale biological structure.

We have a large data set of microstructure profiles obtained with a laser/fiber optic profiling system. The concurrent measurements of physical and biological variables over small scales (0.02m) has allowed us to determine the temporal and spatial scales of correlation between these variables. We have approached the project objectives through extensive data analysis of these profiles.

We have developed, with the help of Dr. Mary-Elena Carr, the postdoctoral associate supported by this project, a suite of analysis programs which permit us to evaluate bio-physical coupling within the upper 100m of the water column at two sites off the Oregon coast. We have focussed on a series of microstructure physics/fluorescence profiles obtained during late summer, 1989, and a series of microstructure physics/light scatter profiles obtained during spring, 1991. In all profiles, we derived estimates of instantaneous dissipation rates (over 10cm intervals) based upon microscale velocity shear. We have developed a criterion to locate thin layers of pigment fluorescence or particulate light scattering, and have been exploring the relationship of these thin layers of biological structure to the associated physical microstructure and finestructure. In addition, we have explored the relationship between thin layer occurrence and temperature steps.

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We have found that the upper ocean is composed of multiple thin layers of phytoplankton biomass (Figure 1), and these thin layers are often associated with small-scale features in physical variables. For example, we have found that the mode of the size-frequency distribution of layer thickness is between 20-40cm (Figure 2), and these thin layers are located within regions of lower turbulent kinetic energy dissipation (relative to nearby regions) (Figure 3). In addition, we have documented the occurrence of thin layers in association with small-scale temperature and density structure.

The investigation of biological/physical coupling has yielded exciting and provocative results about the size and persistence of small-scale structure in the upper ocean (Figure 4). In particular, we think that the relationship of local minima in TKE dissipation to local maxima in phytoplankton biomass may be a crucial component in understanding the temporal and spatial scales of correlation between physical and biological parameters.

List of Publications and Presentations

Presentations:

Carr, M-E., T.J. Cowles, R.A. Desiderio, J.N. Moum, J.R. Zaneveld. Physical-biological coupling at small scales: Do phytoplankton layers occur at density steps? AGU Fall Meeting, San Francisco, CA, December, 1992

Carr, M-E., T.J. Cowles, R.A. Desiderio, J.N. Moum, J.R. Zaneveld. Physical-biological coupling at small scales: Do phytoplankton layers occur at density steps? AGU Fall Meeting, San Francisco, CA, December, 1992

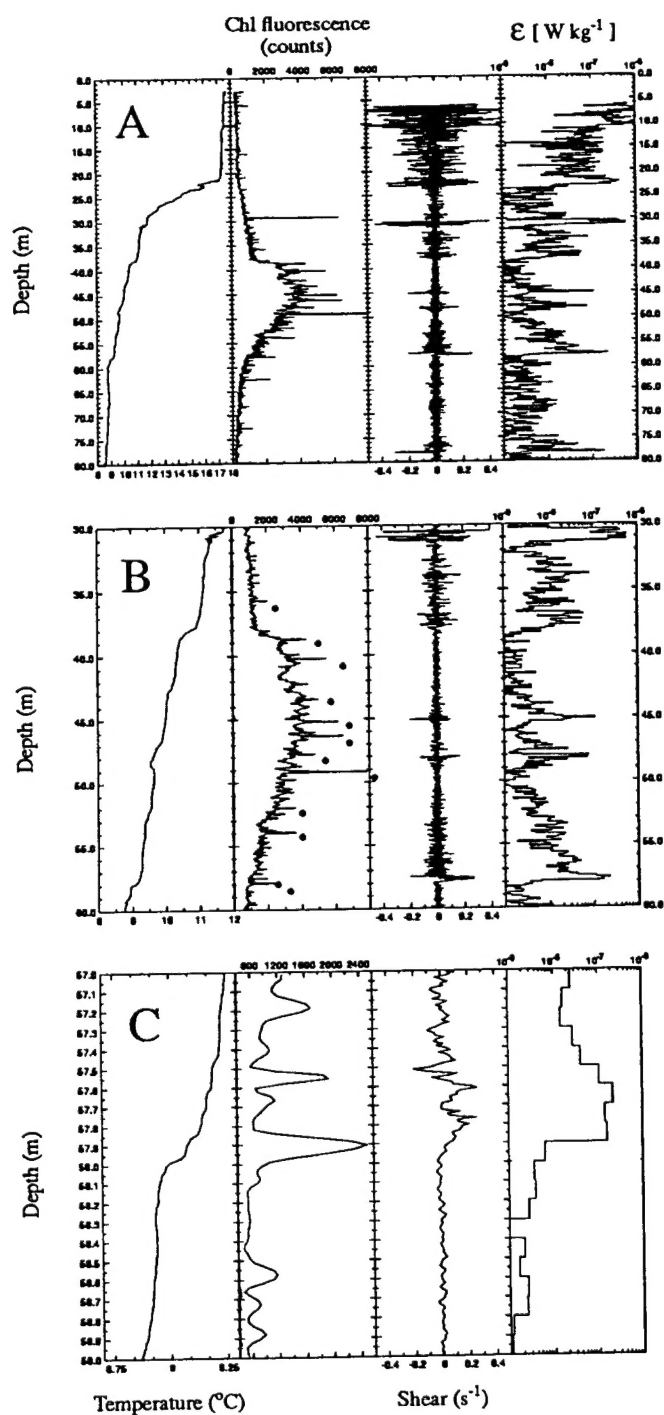
Cowles, T.J., R.A. Desiderio, M-E. Carr. Thin layers of phytoplankton biomass within the euphotic zone: implications for remote sensing. AGU Fall Meeting, San Francisco, CA, December, 1992

Cowles, T.J., M-E. Carr. Small-scale physical-biological interactions: trophic implications of persistent thin layers of phytoplankton biomass. Third Scientific Meeting of The Oceanographic Society, Seattle, WA, April, 1993

Publications:

M.-E. Carr, T. Cowles, R. Desiderio, J. Moum, and R. Zaneveld. Persistence and expected residence times for buoyant and non-sinking particles. *In manuscript*. To be submitted to Journal of Geophysical Research.

Cowles, T.J., M.-E. Carr, R. Desiderio, and J. Moum. Temporal persistence of thin layers of biological microstructure. *In manuscript*. To be submitted to Journal of Geophysical Research.



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Figure 1. A) Vertical profile (0-80m) of temperature, chlorophyll fluorescence, horizontal velocity shear, and 10cm estimates of turbulent kinetic energy dissipation during an interval of low wind stress ($< 3ms^{-1}$). B) An expanded view of the 30-60m segment of this vertical profile, with thin layers identified with circles. C) A 2m segment (57-59m) of this profile. Note the association of the fluorescence layer with the temperature step at 57.95m, as well as the association with the diminished TKE dissipation at the same depth.

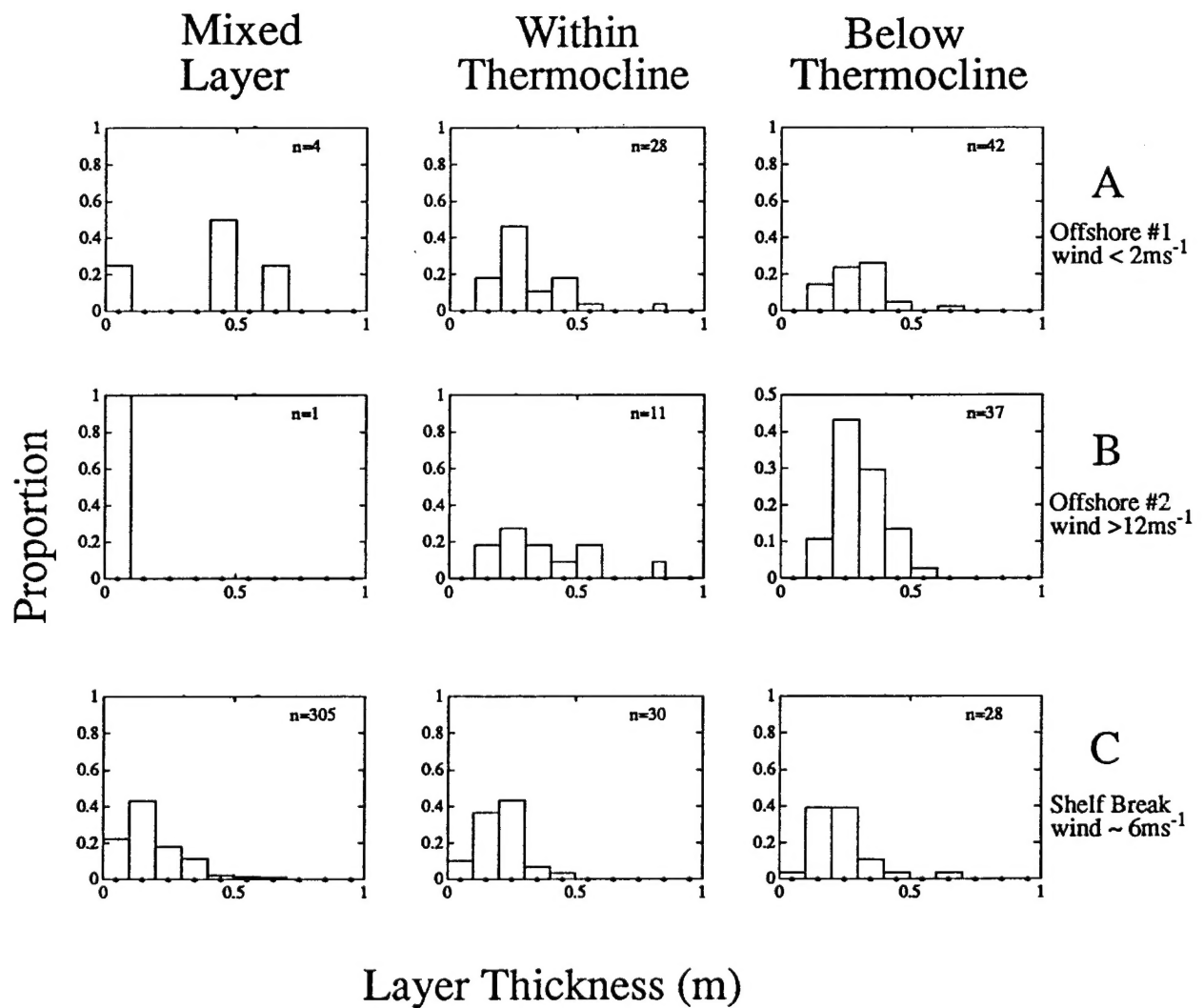


Figure 2. Frequency histograms of chlorophyll fluorescence layer thickness within and below the seasonal thermocline during three time intervals with different wind forcing. A) Offshore under low wind conditions ($< 2\text{ms}^{-1}$); B) Offshore under high wind condition ($> 12\text{ms}^{-1}$); C) Shelf break under intermediate wind conditions ($\sim 7\text{ms}^{-1}$). In all cases the mode of the layer thickness distribution is less than 50cm, and usually between 20cm and 40cm.

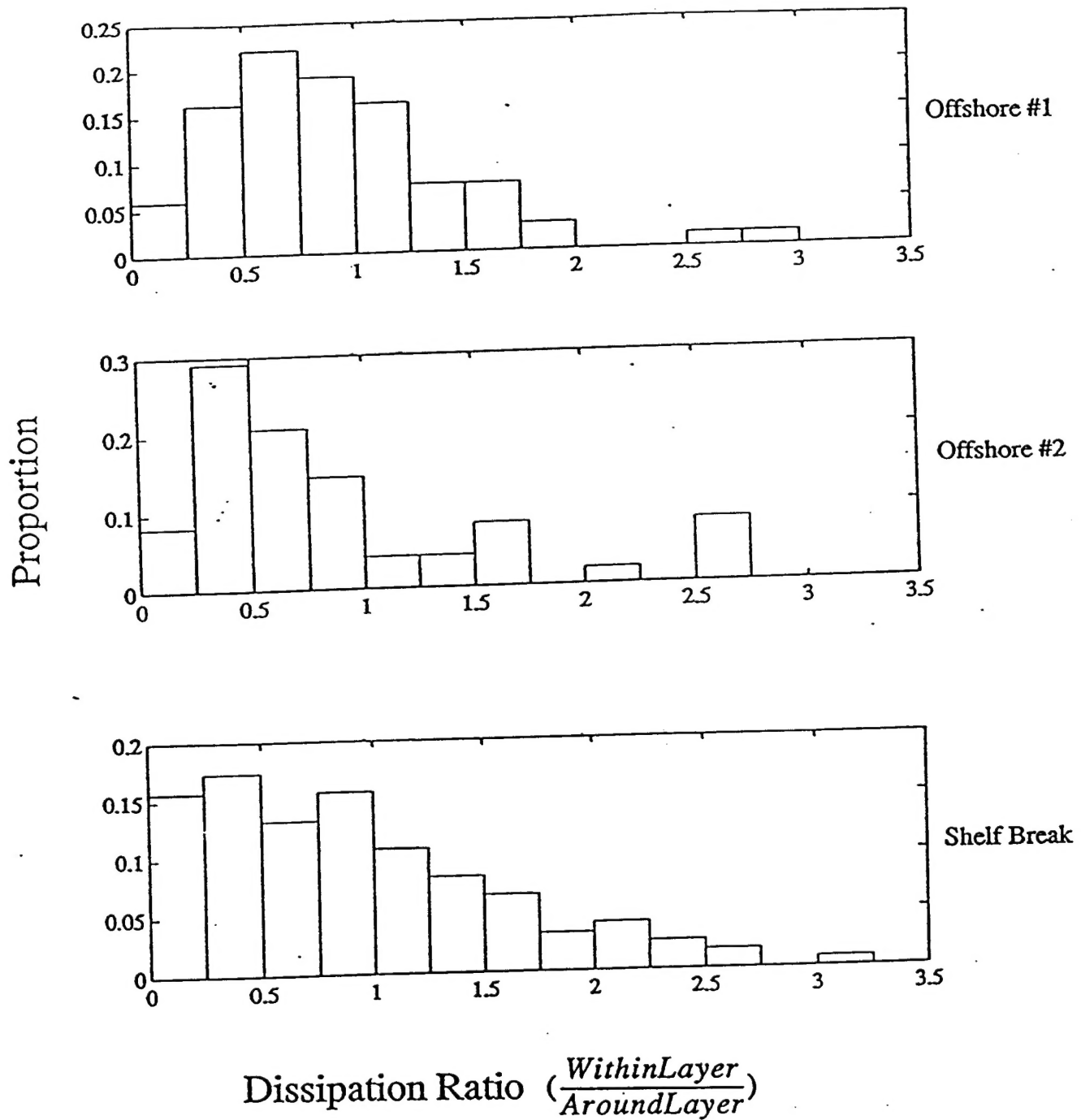


Figure 3. Frequency distribution of the ratio of dissipation WITHIN a fluorescence layer to dissipation OUTSIDE ($\pm 50\text{cm}$ of layer) for the three time series, two offshore (drops 7-13, drops 59-64) and one shelf break (drops 78-88), based on 10cm estimates of dissipation (Yamazaki and Lueck 1990). The distributions suggest that most of the fluorescence layers occur within local minima of dissipation.

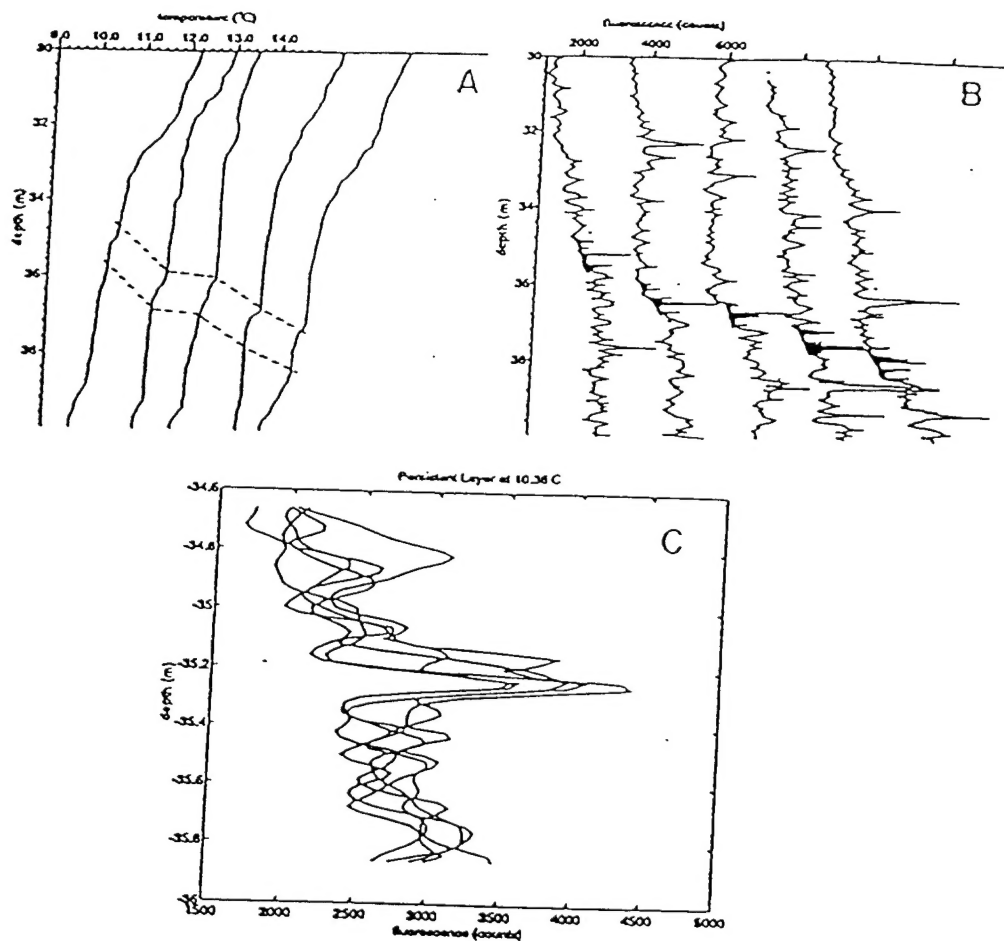


Figure 4. Vertical detail (30-40m) of (a) temperature and (b) fluorescence from a series of microstructure profiles obtained off the Oregon coast with 8 mins between successive profiles. In (a) and (b), the five profiles are offset to show each trace, with the axis values matching the first profile. In (a), the 1m segment of the temperature profile centered on 10.38°C is indicated by the dotted lines. The vertical segments of the fluorescence profile (b) which correspond to the 10.38°C temperature interval have been highlighted, with a local maximum visible within each segment. (c) The 1m vertical segments of pigment fluorescence identified in Figure 2b are plotted such that the depth of 10.38°C is centered at 35.25m. The local maximum in fluorescence now can be seen as a persistent thin layer.



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